An Efficiency Analysis of European Countries' Railways

Pavlyuk, Dmitry
Transport and Telecommunication Institute

24. August 2008

An Efficiency Analysis of European Countries' Railways

Pavlyuk Dmitry
Candidate of Economic Science, Transport and Telecommunication Institute
Lomonosova 1, Riga, LV-1019, Latvia
Phone: (+371)29958338. Email: dmitry@magicwebsolutions.co.uk

ABSTRACT

This study uses stochastic frontier analysis for estimating efficiencies of railways systems in European countries. We consider railways as a system which uses its infrastructure (length of lines worked, numbers of cars and wagons, staff strength) and a scale of market (number of habitants and tourists) for transporting passengers and freights. We estimate efficiencies of freight and passenger transportations separately on the base of different models.

We use the database provided by International Union of Railways, which includes annual statistical data about biggest European railways companies from 1997 to 2006 to estimate model parameters. Railways systems show huge variations in technical efficiency between different countries and also between freight and passenger transportation within the same country. The study also contains the analysis of dependencies between calculated railways efficiency estimates and popular economic indicators.

Keywords: stochastic frontier, efficiency, railway systems

Introduction

European railways were originally organised as separated state monopolies, and this situation saves in many countries so far. From 1970 railways are losing their positions in passenger and freight transportation, the railways market share is falling comparing with other transport systems. The market share of passenger carriage (in passenger-kilometres) implemented by railways is decreased from 10.4% in 1970 to 6.1% in 2006, the market share of freight transportations (in tonnes-kilometres) is also decreased from 20.1% in 1970 to 10.5% in 2006.

This negative trend led to necessity of economic reforms in European railways. The main directions of the reform developed by the European Commission are to de-monopolise the railways sector and to create an open competitive all-European railways market. The European Commission directive 91/440/EEC became the base document of the reform. The directive was enacted in 1991 and contains recommendations for gradual liberalisation of European railways. The main components of the reform, defined in the directive, are:

- separation of infrastructure management from transport operations. This separation can be implemented in three steps – accounting separation, organizational separation, and full (institutional) separation;
- creating conditions for access of foreign (European) railways companies to national transportation markets.

The reform implementation should lead to the railways sector competitiveness growth and increasing of its efficiency.

At the same time the level of market competitive is one of a number of components influenced the efficiency of railways transportation. National railways are functioning in different environments, and it's based on differences in European economics. Foe example, the relative level of GDP per capita in Netherlands was 130.4 which are more than twice higher than in Latvia in the same year (53.6). The existed railways infrastructure is also very heterogeneous. The density of railways network (a ratio of an aggregate length of railway lines to a country area) in Latvia is 12 times higher than in Spain (0.0351 in Latvia versus 0.0029 in Spain). Also there is a pronounced orientation of railways to passenger or freight transportation. A ratio of a passenger transportation volume (passenger-kilometres) to a freight transportation volume (tonnes-kilometres) varies from 0.03 in Estonia to 2.74 in Greece (2006), so there are 33 tonnes of cargo transported on one kilometre for each passenger transported on one kilometre in Estonia, and only 0.36 tonnes – in Greece. The different orientations make the estimation of European railways efficiencies more difficult.

The reform implementation and necessity of railways efficiency estimation attracted an attention of scientific community to this problem. There are some studies dealt with railways efficiencies published in the course of latest decade – Coelli and Perelman 2000 [1], Cantos, Pastor, and Serrano 2002 [2], Friebel, Ivaldi, and Vibes 2005 [3], Asmild, Holvad, Hougaard, and Kronborg 2008 [4], Wetzel 2008 [5]. These studies are based on the non-parametric methods of efficiency estimation (Data Envelopment Analysis, DEA in [2] and [3]) as well as parametric methods (Stochastic Frontier Analysis in [1], [3], and [5]). The majority of studies indicate a significant level of inefficiency in European railways.

Also the positive effect of the reform is stated (Friebel specified positive effects of consecutive reform implementation and zero or negative effects in case of simultaneous reformation of different railways components).

Despite the significant number of studies in this area, there is no uniformity in understanding of the railway system functioning results. The problem is that any railway system carries out freight and passenger transportation, which are quite different results. Some authors ([3]) consider one of that two railway system outputs only and create models for freight and passenger transportation separately. This approach has a very serious shortcoming – usually it's impossible to separate system resources (infrastructure, staff) used for passenger and freight transportation, but usage of overall resources leads to biases in efficiency estimates due to different orientation of railway systems. Other authors consider a railway system as solid and create models with two simultaneous outputs ([5]).

In this study we consider three railways efficiency models:

1. a model of passenger transportation efficiency, Model PKM
2. a model of freight transportation efficiency, Model TKM
3. a model of overall efficiency with two simultaneous outputs, Model Multi

For efficiency estimation we use a method based on the stochastic efficiency frontier [6], which allows us to receive annual efficiency values for European railways. We consider correlations between estimated efficiency values and railway systems characteristics as well as macroeconomic and demographic indicators. Also we study the dynamics of efficiency values for selected time frame (from 1997 to 2006).

Methodology

To use the stochastic frontier approach we consider national railways as a system with a number of inputs (resources) and outputs (results). The method is based on the theory of production possibility sets, its frontier and production functions theory.

In the stochastic frontier model we assume that a railway system uses an resource input vector of non-negative components $x=(x_1, x_2, \ldots, x_N)\in R_+^N$ for producing a result vector $y=(y_1, y_2, \ldots, y_M)\in R_+^M$.

The key conceptions of stochastic frontier analysis are the production possibility set $T=\{(y, x) \mid {\scriptstyle x \text{ sufficient for producing } y}\}$ and the production frontier of this set $f(x)=\max\{y \mid {\scriptstyle (y, x)\in T}\}$.

The essence of the method is to construct an efficiency frontier for sample of national railways, to estimate a distance of each railway system from this frontier (as an inefficiency level) and to discover relations of efficiency values with a defined set of factors.

To estimate an individual inefficiency of a railway system we use Sheppard's input distance function [7] from an efficiency frontier $D_I(y, x) = \sup_\delta\{\delta \mid {\scriptstyle (y,\ x/\delta)\in T}\}$. The input distance shows the highest possible value of proportional reduction of used resources (the output stays the same). In theory it is possible to use another option – an output distance function $D_O(y, x)$. The output distance shows a possibility of proportional increasing of results (with the same level of resources used). In practice the distance function is usually selected on the base of manageability of inputs and outputs (more manageable function is preferred). In our case (railways) the results (transported passengers and freights) in our opinion are less manageable than the resources (staff strength, and a number of passenger cars, freight wagons, and locomotives). This statement can be explained by the fact that volumes of transportation are highly correlated with economic and social situation in the country, and also are affected by liabilities to government. As a result we use the input distance function in all our models.

The stochastic frontier model can be formalised as:

$$y = f(x, \beta) + \varepsilon,$$

$$\varepsilon = v - u, v \sim N(0, \sigma_v^2), u \geq 0,$$

where

y – an output;

x – a vector of resources;

f – a production function;

β – a vector of unknown coefficients;

ε – a composite error term.

The first component of composite error term, v, shows the random variation of the efficiency frontier, and the second one, u, shows the technical inefficiency of the railway system functioning. The individual efficiency of the railway system i is estimated as [8]:

$$TE_i = e^{-E(u_i|\varepsilon_i)},$$

where $E(u_i|\varepsilon_i)$ – conditional expectation of u_i given estimated ε_i.

Usage of maximum likelihood method allows to receive asymptotically consistent estimates for all unknown model parameters, but requires additional assumptions about probability distributions of the error term components. The usual assumption in the stochastic frontier model is the normal distribution of the random component v_i with zero mean. The distribution of the second error term component u_i can be selected by researcher (subject to mandatory non-negativeness of values). We used the truncated normal distribution for u_i with a conditional mean (the first distribution parameter depends on the set of factors z, possibly correlated with inefficiency) [9]:

$$u_i \sim N^+(\delta_0 + \sum_{i=1}^{m} \delta_i z_{it}, \sigma_u^2)$$

Also we need to make some assumptions about the functional form of the efficiency frontier (function *f*) to estimate unknown parameters. The selection of the frontier functional form is another key decision for model specification as the results are strictly depended on it. In this study we have estimated the models with a Cobb-Douglass function, a Translogarithmic function, and a Translogarithmic function with time components.

One of the main advantages of the stochastic frontier methods comparing to deterministic methods (DEA) is the probabilistic nature of the estimated parameters. The methodology assumes the presence of uncertainty in the results and allows estimating it. So we were able to test hypotheses about alternative model specifications and parameter values on the base of parameters statistical properties.

So for model specification we choose different frontier functional forms, inefficiency distribution forms, and a set of factors affected an inefficiency of railways. Combinations of these factors are the alternative model specifications, which were compared using a standard likelihood ratio test.

The resulting forms of the model for railway transportations with one output y (a number of passenger-kilometres for Model PKM and a number of tonne-kilometres for Model TKM), a Translogarithmic form of the frontier varying in time and with a truncated normal inefficiency distribution are the next:

$$\ln(y_{it}) = \beta_0 + \sum_{i=1}^{n} \beta_i \ln(x_{it}) + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=i}^{n} \beta_{ij} \ln(x_{it}) \ln(x_{jt}) + \sum_{i=1}^{n} \tau_i \ln(x_{it}) \cdot t + \nu_{it} - u_{it},$$

$$\nu_{it} \sim N(0, \sigma_v^2), u_{it} \sim N(\delta_0 + \sum_{i=1}^{m} \delta_i z_{it}, \sigma_u^2),$$

Also we need to estimate the efficiency in case of K (more than one) outputs. To do it we use the model below (Model Multi) [1]:

$$-\ln(x_{it}^*) = \beta_0 + \sum_{i=1}^{k} \alpha_i \ln(y_{it}) + \sum_{i=1}^{n} \beta_i \ln(x_{it}/x_{it}^*) + \frac{1}{2}\sum_{i=1}^{k}\sum_{j=i}^{k} \alpha_{ij} \ln(y_{it}) \ln(y_{jt}) +$$
$$+\frac{1}{2}\sum_{i=1}^{n}\sum_{j=i}^{n} \beta_{ij} \ln(x_{it}/x_{it}^*) \ln(x_{jt}/x_{it}^*) + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=i}^{k} \gamma_{ij} \ln(x_{it}/x_{it}^*) \ln(y_{jt}) +$$
$$+\sum_{i=1}^{k} \eta_i \ln(y_{it}) \cdot t + \sum_{i=1}^{n} \tau_i \ln(x_{it}) \cdot t + \nu_{it} - u_{it},$$

where x^* – a normalising input vector component. We selected an overall length of railway lines in the country as a normalizing component, because it is more difficult to change this input comparing with others.

Data

Data set includes some characteristics of railways infrastructure and transportation process and also macroeconomics and social indicators for 22 European countries from 1997 to 2006. Selected time frame covers the implementation of the liberalisation reform in the majority of countries (data for 2007 is not full enough for this moment).

Data was received from the sources below:

1. Railissa Database of the International Union of Railways (UIC) includes values for many characteristics provided by UIC members (almost all European railways undertakings are members of the Union). The database has an access limitations (for UIC members only), but some usual characteristics are public. From this database we used data about volumes of passenger and freight transportations (by undertakings), infrastructure characteristics (overall length of railway lines, number of rolling staff by types), and staff strength. We grouped the collected data by country.

2. Eurostat database was used for macroeconomic and demographic information – relative GDP per capita, population density, and number of tourists.
3. Reports of European Commission about the railways reform implementation. Also data about the reform realisation by countries were kindly provided by Dr. Torben Holvad, an economic consultant of European Railway Agency, ERA.

The important moment in the stochastic frontier model specification is defining of three groups of factors – outputs (results of system functioning), inputs (resources), and factors correlated system inefficiency. At the first step we decided to avoid of using indicators, measured in amounts of currency (profit, maintenance expenditures, investments) due to different purchasing power and overall economic situation in different countries.

We defined results of railway systems functioning as a number of passenger-kilometres (*pkm*) for passenger transportations and a number of tonnes-kilometres (*tkm*) for freight transportations. We considered (and declined) alternative variants of the output specification used by some authors – absolute values of passengers and tonnes of cargo transported, and a number of train-kilometres. The resulting choice was passenger-kilometres and tonnes-kilometres, because, in our opinion, these indicators show the real economic (non-technical) effects of railways more accurately than others. Also these indicators allows grouping of long (intercity) and short (local) trips, which is especially important for passenger carriage.

We used three railways characteristics as system resources – an overall length of railway lines (*length*, including narrow-gauge), a number of passenger cars and coaches (*passengercars*, all types), and a number of freight wagons (*wagons*, all types).

Also we considered a possibility to include into the model such resources as electricity and oil/lubricants, but UIC didn’t provide this information by request (this info is open for members only). We suppose that the overall technology (locomotive types, cars/wagons undercarriage) is similar for all European countries and that's why the indicators above are highly correlated with rolling staff numbers.

We selected the factors below as correlated with a railway systems inefficiency level:

- GDP per capita as an indicator of economic power *(gdpp*). For our calculations we used the relative GDP calculated on the base of purchasing-power parity and normalised by an average value of 27 European countries;
- the population density(*pop_den*);
- the tourist «density» – a number of tourist per country's area square kilometre (*tou_den*);
- the railway lines density – a number of kilometres of railway lines per country's area square kilometre (*len_den*).

All four indicators are included into the model in the logarithmic form, for considering their relative, but not absolute changes.

The level of railway liberalisation reform implementation is included as a set of dummy variables:

- *OrgSeparation* – an organisational separation of infrastructure management and transporting process. We decided to not include the separation at the accounting level, because all countries (except Estonia) already implemented this point of the directive and many of them – before 1997.
- *InternAccess* – access for foreign railway companies to the national transportation market.
- *PassService* – a normative base for internal competition amongst passenger carriage companies. The variable is not included into the Model TKM.
- *FreightService* – a normative base for internal competition amongst freight carriage companies. The variable is not included into the Model PKM.

Results

The functional form of a frontier for each of three considered models (Model TKM, Model PKM, and Model Multi) was chosen from the next options:

1. Cobb-Douglass function
2. Translogarithmic function
3. Translogarithmic function with time components

We compared the model using the likelihood ratio test; the results are presented in Table 1.

Table 1. Concurrent model specification comparing

Null hypothesis H_0	Alternative hypothesis H_1	$L(H_0)$	$L(H_1)$	Λ	Number of restrict.	χ-crit., 99%	Conclusion
Model PKM							
Cobb-Douglass, $\beta_{ij}=0$	Translog	-73.53	6.20	159	6	16.8	H0 rejected
Translog $\tau_i=0$	Translog with time components	6.20	-116.9	-244	3	11.34	H0 accepted
Model TKM							
Cobb-Douglass, $\beta_{ij}=0$	Translog	-235.39	-214.43	41.92	6	16.8	H0 rejected
Translog $\tau_i=0$	Translog with time components	-214.43	-260.92	-92.9	3	11.34	H0 accepted
Model Multi							
Cobb-Douglass, $\beta_{ij}=0$	Translog	-10.03	166.11	352	13	27.68	H0 rejected
Translog $\tau_i=0$	Translog with time components	166.11	163.95	-4.32	5	15.08	H0 accepted

So for all three models the translogarithmic frontier function without time components is the best one. The absence of time components in the frontier function can be explained by:

- absence of technological changes in railway undertakings during the selected time frame;
- shortage of sample volume for estimating more flexible functional form of a frontier.

The model estimation results ([10]) are presented in Table 2.

Table 2. Models estimation results

Model PKM - Translog		**Model TKM – Translog**		**Model Multi – Translog**	
ln(pkm)		ln(tkm)		-ln(length)	
Frontier	|*Coef.*	*Frontier*	*Coef.*	*Frontier*	*Coef.*
ln(length)	-2.16***	ln(length)	-4.16***	ln(pkm)	-0.23 **
ln(staff)	-2.67***	ln(staff)	0.95	ln(tkm)	0.27***
ln(cars)	5.65***	ln(wagons)	0.03	ln(staff/length)	-1.32***
$\ln(\text{length})^2$	0.23***	$\ln(\text{length})^2$	0.18***	ln(cars/length)	0.66***
$\ln(\text{staff})^2$	0.21 **	$\ln(\text{staff})^2$	-0.003	ln(wagons/length)	0.60***
$\ln(\text{cars})^2$	0.12***	$\ln(\text{wagons})^2$	-0.04	ln(staff/length)* ln(cars/length)	-0.17***

ln(length)* ln(staff)	0.18	ln(length)* ln(staff)	0.02	ln(staff/length)* ln(wagons/length)	-0.05
ln(length)* ln(cars)	-0.40***	ln(length)* ln(wagons)	0.13***	ln(cars/length)* ln(wagons/length)	0.16***
ln(staff)* ln(cars)	-0.36 **	ln(staff)* ln(wagons)	-0.07***	ln(pkm)* ln(tkm)	-0.06***
				ln(staff/length)* ln(tkm)	0.03
				ln(staff/length)* ln(pkm)	0.11***
				ln(cars/length)* ln(tkm)	-0.04 **
				ln(cars/length)* ln(pkm)	0.06***
				ln(wagons/length)* ln(tkm)	0.00
				ln(wagons/length)* ln(pkm)	-0.06***
				$\ln(\text{staff/length})^2$	0.11***
				$\ln(\text{cars/length})^2$	0.12***
				$\ln(\text{wagons/length})^2$	0.02
Inefficiency		*Inefficiency*		*Inefficiency*	
OrgSeparation	-0.15 **	OrgSeparation	9.40***	OrgSeparation	-0.06***
InternAccess	0.22***	InternAccess	-5.51 **	InternAccess	0.32***
PassService	-0.08	FreightService	-17.67***	PassService	-0.21***
ln(gdpp)	-0.63***	ln(gdpp)	-2.45***	FreightService	0.11 **
ln(pop_den)	-4.22***	ln(pop_den)	18.68***	ln(gdpp)	-0.47***
ln(len_den)	18.12***	ln(len_den)	-14.39***	ln(pop_den)	-1.97***
ln(tou_den)	-0.002***	ln(tou_den)	0.02***	ln(len_den)	7.10***
				ln(tou_den)	0.00

*, **, *** – the coefficient is significantly different from zero at the 90, 95, and 99 % level respectively

The most interesting values are the estimated coefficients for factors, correlated with inefficiency level. As we estimate a distance from the efficiency frontier then the negative coefficient value for a factor shows that the distance is decreasing when the indicator is growing and that's why it indicates a positive influence of the factor on the railway system efficiency.

The coefficient of *OrgSeparation* is significant in all three models. In the Model PKM and the Model Multi the organisational separation of infrastructure and transport services shows positive effect on the railways efficiency, but in the Model TKM – negative effect. It can be explained as increasing expenditures for separated systems management and coordination make greater negative influence on cargo carriage.

A possibility for access of foreign companies to the national railway market (*InternAccess*) has a negative influence on the efficiency of passenger transportation and the efficiency of the railway system as whole. We have no doubt the liberalisation reform necessity in a long-term outlook, but have to note that railway systems efficiencies are decreasing during the transition period. The opening of the railway market for national companies (*PassService* in the Model PKM and *FreightService* in the Model TKM) makes a positive influence on the railways efficiency (which match our expectations).

The coefficients for environment variables are also highly significant. The relative level of GDP per capita ln(*gdpp*) has a significant negative coefficient, which indicates higher railways efficiency level in developed countries.

The population density ln (*pop_den*) is a positive factor for efficiency of passenger transportation and of the overall railways system efficiency and a negative – for efficiency of cargo traffic. The influence of the tourist “density” ln(*tou_den*) is also matched our expectations – a positive effect for passenger carriage efficiency and a negative – for cargo carriage. Note that many of system resources showings have opposite signs for passenger and cargo carriage. It can be a consequence of mutual resource usage and different railways orientations. For example, countries with high population and tourist density have to cater for passenger carriage to the prejudice of cargo carriage.

On the base of the models above we estimated efficiency levels for sample countries from 1997 to 2006 (Table 3).

Table 3. Estimated efficiency levels of European railway systems

	Model	**Efficiency, %**									
		1997	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*
Austria	TKM	64	66	68	76	78		79	83	78	
	PKM	30	32	32	34	33		34	34	35	
	MULTI	80	84	85	87	87		87	88	87	
Belgium	TKM	44	44	43	44	42	43	43	45	47	48
	PKM	38	30	31	32	32	32	32	32	38	40
	MULTI	97	82	82	83	83	83	83	85	89	91
Bulgaria	TKM	40	36	29	33	25	24	28	27	27	27
	PKM	13	13	13	13	13	14	14	15	15	16
	MULTI	69	68	64	65	63	58	58	59	60	61
Czech Republic	TKM				72	65	60	60	58	59	62
	PKM				7	7	7	8	9	9	9
	MULTI				50	50	48	51	52	53	55
Denmark	TKM	10	11	10	11	76	83	84	87		0
	PKM	35	34	36	40	40	36	36	37		39
	MULTI	97	97	98	98	98	97	97	98		97
Estonia	TKM	40	40	52	54	57	69	74	79	86	86

	PKM	18	18	16	17	17	18	19	20	22	24
	MULTI	82	81	72	74	67	70	72	73	82	85
Finland	TKM	65	66	66	69	68	68	72	74	72	81
	PKM	39	33	33	33	33	33	33	33	33	33
	MULTI	99	95	95	96	95	95	95	96	96	96
France	TKM		64	55	58	52	51	47	47	43	40
	PKM		41	37	38	38	38	37	37	40	38
	MULTI		98	90	91	91	91	89	89	90	89
Germany	TKM	67	69		78	79	73	69	83	80	85
	PKM	23	24		32	32	32	31	34	36	36
	MULTI	84	89		93	94	89	86	91	91	92
Greece	TKM				3	3	2	3	4	5	5
	PKM				37	37	38	38	38	39	40
	MULTI				90	90	89	91	92	92	92
Italy	TKM	61	60	58	59	60	54	52	55	50	51
	PKM	57	57	47	59	59	58	58	58	58	59
	MULTI	98	98	92	97	97	97	97	97	97	97
Latvia	TKM	87	82	79	86	88	90	96	95	97	92
	PKM	13	14	11	11	12	13	13	14	17	18
	MULTI	72	76	61	59	60	62	63	65	72	74
Lithuania	TKM						71	84	87	92	94
	PKM						16	17	17	18	18
	MULTI						69	70	71	72	74
Netherlands	TKM		16	14			14	15	92		
	PKM		99	99			99	99	100	100	100
	MULTI		99	99			99	100	99	99	99
Poland	TKM	96	92	88	89	91	91	91	92	88	86
	PKM	11	9	10	10	13	13	13	15	15	16
	MULTI	65	54	56	56	60	61	64	68	68	69
Portugal	TKM	16	15	13	16		17	17	19	21	21
	PKM	35	36	36	36		37	37	39	40	41
	MULTI	93	93	90	90		92	91	97	98	98
Slovak Republic	TKM	77	74	58	64	60	57	55	0	0	0
	PKM	10	10	10	10	11	12	13	13	14	14
	MULTI	60	60	58	59	61	62	62	63	66	67
Slovenia	TKM	20	20	19	19	19	20	21	22	23	24
	PKM	20	20	21	21	20	21	23	27	28	28
	MULTI	93	94	94	95	94	95	97	98	98	98
Spain	TKM		83	84	86	86	85	87	87		85
	PKM		51	54	55	55	56	57	58		73
	MULTI		97	97	97	98	98	98	98		97
Sweden	TKM	82	83	85	90		62	66	68		61
	PKM	31	31	32	32		32	32	33		33
	MULTI	89	89	93	96		91	87	86		90
United Kingdom	TKM	91			88	64	78	78			
	PKM	57			66	65	66	64			
	MULTI	98			97	96	97	97			

We note the presence of different railway system orientations (passenger or freight) in the estimated efficiency levels. In Latvia, Poland, Czech Republic, and Estonia the efficiency of cargo carriage is significantly higher than passenger transportation, and there is an opposite situation in Netherlands, Denmark, and Portugal – passenger traffic is much more efficient than cargo carriage.

Also it should be noted that efficiency levels estimated for railways as whole (the Model Multi) are not a simple average of passenger and cargo traffic efficiencies. For example, Italian railway system has not very high passenger and cargo carriage efficiency levels (56% and 57% in average respectively), but the overall system efficiency is very high (97% in average), so it is situated near to the frontier for simultaneous cargo and passenger transportation.

Conclusions

In this study we used stochastic frontier method to build models of efficiency of passenger and cargo transportation and overall railways efficiency. These three models, estimated on the same data sample, allow us comparing the results of different approaches to railways efficiency measurement. This point presents a novelty of our research and it creates a base for future studies.

We have analyzed influence of different environment factors on the railways efficiency level. The railways liberalisation has a positive influence and increases the overall system efficiencies. Some points of the reform (international access to the national railway market) considerably increase management and coordination expenditures and the efficiency growth doesn't cover this negative effect in a short term. Also we got expected positive influence of country's economic power on its railways efficiency. High population and tourist densities are led to increasing of passenger traffic efficiency.

We estimated efficiency values for 22 European countries from 1997 to 2006. Estimated efficiency levels indicate different railway system orientations – to cargo carriage (Latvia, Poland, and Czech Republic) or to passenger transportation (Netherlands, Denmark). Railways of European countries with the most developed economics (Germany, France, United Kingdom, and Italy) are more balanced (in terms of passenger and cargo carriage) and have high levels of overall efficiencies.

We have to note some shortcomings of this study. Due to data limitations we had to exclude some European countries (Hungary, Luxemburg, and Switzerland) and some years for other countries (United Kingdom) from the sample. Also there are some points opened for future investigations – including into the models additional resources (electricity, oil, and lubricants) and produced results, calculating and analysing of resource elasticises and confidence intervals for efficiency levels, considering of efficiency dynamics.

Also it should be noted that all constructed models use quantity data for resources and outputs only; we don't take into account such important railways efficiency aspects as finances, safety, punctuality, and ecological compatibility.

Bibliography

1. Coelli T., Perelman S. Technical efficiency of European railways: a distance function approach, *Applied Economics*, №32, 2000, pp. 1967–1976.
2. Cantos P., Pastor J. M., Serrano L. Cost and revenue inefficiencies in the European railways, *International Journal of Transport Economics*, №29, 2002, pp. 279–308.
3. Friebel G., Ivaldi M., Vibes C. Railway (De)regulation: A European Efficiency Comparison, *CEPR Discussion Paper*, №4319, Centre for Economic Policy Research, London, 2005, 47 p.
4. Asmild M., Holvad T., Hougaard J.L., Kronborg D. Railway Reforms: Do They Influence Operating Efficiency?, *Discussion Papers*, 08-05, University of Copenhagen, 2008, 28 p.
5. Wetzel H. European Railway Deregulation: The Influence of Regulatory and Environmental Conditions on Efficiency, *Working Paper Series in Economics 86*, University of Lunenburg, 2008, pp. 36.
6. Aigner D.J., Lovell C.A.K, Schmidt P. Formulation and Estimation of Frontier Production Function Models, *Journal of Econometrics*, №6, 1997, p. 21-37.
7. Shephard, R.W. *The Theory of Cost and Production Functions*. Princeton: Princeton University Press, 1970, 308 p.

8. Johdrow J., Lovell C.A.K., Materov I.S., Schmidt P. On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model, *Journal of Econometrics*, №19, 1982, pp. 233-238.
9. Stevenson R.E. Likelihood Functions for Generalized Stochastic Frontier Estimation, *Journal of Econometrics*, Vol. 1, №13, 1980, pp. 57-66.
10. Coelli T.J. A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation, *CEPA Working Paper*, 1996, 32 p.